EAC evaluation methods: Do they still work?

Article · January 2002

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Author:	David Christensen, Ph.D.	Carl Templin, Ph.D.
Mailing address:	College of Business Southern Utah University 351 West Center Street Cedar City, Utah 84720	College of Business Southern Utah University 351 West Center Street Cedar City, Utah 84720
Email:	ChristensenD@suu.edu	Templin@suu.edu
Phone:	(435)865-8058	(435)586-7705
Fax:	(435)586-5493	(435)586-5493

BIOGRAPHIES

Dr. David Christensen is an Associate Professor of Accounting at Southern Utah University at Cedar City, Utah. After earning his Ph.D. at the University of Nebraska in 1987, he joined the faculty of the Air Force Institute of Technology, where he taught undergraduate and graduate courses in earned-value for over 10 years. Dr. Christensen is a CMA, CGFM, and CCEA and is active in the Society of Cost Estimating and Analysis (SCEA), the American Accounting Association (AAA), and the Institute of Management Accounting (IMA).

Dr. Carl Templin is the Dean of the College of Business and Technology and Professor of Management at Southern Utah University. After earning his Ph.D. at Arizona State University in 1988, he joined the faculty of the Air Force Institute of Technology, where he taught graduate courses in contracting management for seven years and served as Associate Dean and acting Dean of the School of Logistics and Acquisition Management. Dr. Templin is Fellow of the National Contracting Management Association and is a member of the National Association of Purchasing Management.

EAC EVALUATION METHODS: DO THEY STILL WORK?

ABSTRACT

Christensen (1999) describes several methods to evaluate the accuracy of the estimated final cost of a defense acquisition contract, termed the "Estimate at Completion" (EAC). The methods are based on DOD experience that cost variances tend to worsen after the 20 percent completion point, and were validated on contracts completed in the 1970s and 1980s. This study tests the validity of two EAC evaluation methods on a sample of defense acquisition contracts completed in the 1990s. Results show the mean cost performance on contracts completed in the 1990s did not worsen significantly from the 20 percent completion point, thus challenging the basic premise of the evaluation methods. We speculate that acquisition reform initiatives, energized by the cancellation of the Navy's A-12 program (c1991), have improved defense cost performance.

BACKGROUND

When Secretary of Defense Richard Cheney cancelled the A12 program in January 1991, he complained in a press conference that no one could tell him the program's final cost (Morrison 1991)[1]. In fact, a Navy investigation led by Chester P. Beach (1990) revealed that there were many estimates of the program's final cost, and some were more reasonable than others. Citing DOD experience with over 400 programs competed since 1977, Beach concluded that the EAC supported by the Navy's program manager was too low, and suggested that similar problems were likely on other defense programs because of an "abiding cultural problem" found in all the military services (Beach 1990); namely, program managers do not always tolerate an accurate EAC, especially when it may jeopardize the funding of the program (Fox 1974, Mayer 1991, Christensen 1993 and 1996).

The "DOD experience" referenced by Mr. Beach pertains to the fact that defense cost variances tend to worsen from the 20 percent completion point. Based on this fact, three "rules of thumb" have been useful for evaluating the accuracy of the EAC (Christensen 1999) and encouraging cost realism:

1. The final cost variance (in dollars or as a percentage) will be worse than the cost variance at the 20 percent completion point.
2. The cumulative cost performance index (CPI) will not change by more than 0.10 from its value at the 20 percent completion point, and in most cases it only worsens.
3. The EAC computed using the cumulative CPI is a reasonable lower bound to the final cost of a defense contract.

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[1] The A12 program was a fixed-price incentive contract in the full-scale development phase when it was cancelled.

Each rule has been validated by empirical analysis of completed defense acquisition contracts (Christensen 1993 and 1996; Christensen and Heise 1993; Christensen and Payne 1992). When an EAC for a major defense acquisition contract violates any of these rules, the accuracy of the EAC should be questioned.[2] However, a recent opinion survey of ten major DOD contractors (Coopers & Lybrand 1997) indicates that current acquisition reform initiatives are improving the cost performance of defense acquisition contracts.[3] This suggests that the rules of thumb validated on contracts completed in the 1970s and 1980s may no longer be valid. In this study we tested the validity of evaluation rules 1 and 2 on contracts completed in the 1990s. The last evaluation rule will be evaluated in another study.

METHODOLOGY

Hypotheses

Null and alternative hypotheses for the two evaluation rules are listed below. Hypotheses 1 and 2 pertain to evaluation rule 1. Hypotheses 3 and 4 pertain to evaluation rule 2. If the null hypotheses are rejected, the evaluation rules are confirmed.

H1o:	$CV\$ \text{ final} - CV\$ \text{ } 20 \geq 0$	The cost variance (CV$) did not worsen
H1a:	$CV\$ \text{ final} - CV\$ \text{ } 20 < 0$	The CV$ worsened
H2o:	$CV\% \text{ final} - CV\% \text{ } 20 \geq 0$	The percent cost variance (CV%) did not worsen
H2a:	$CV\% \text{ final} - CV\% \text{ } 20 < 0$	The CV% worsened
H3o:	$| \text{ CPI final} - \text{CPI } 20 | \geq 0.10$	The cost performance index (CPI) changed by more than 0.10
H3a:	$| \text{ CPI final} - \text{CPI } 20 | < 0.10$	The CPI did not change by more than 0.10
H4o:	$\text{CPI final} - \text{CPI } 20 \geq 0$	The final CPI did not worsen
H4a:	$\text{CPI final} - \text{CPI } 20 < 0$	The CPI worsened

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[2] These rules of thumb are statistical statements about the mean cost performance of defense contracts. While the cost performance of an individual contract may differ from these rules, it would be a statistical outlier in the sense that its cost performance would be more than 2 standard deviations away from the mean.

[3] See Coopers & Lybrand (1997) report for a detailed listing of the acquisition reform initiatives that are intended to improve cost performance of defense acquisition contracts.

The first EAC evaluation rule pertains to cost variances, expressed in dollars or percentages. A cost variance (CV) is defined as the difference between the budgeted cost of work performed (earned value) and the actual cost of work performed.[4] A percentage cost variance is the dollar cost variance divided by earned value.

$$\text{Cost Variance (CV\$)} \quad = \quad \text{Earned Value} - \text{Actual Cost} \qquad\qquad [1]$$
$$\text{Cost Variance (CV\%)} \quad = \quad (\text{CV\$} / \text{Earned Value}) \times 100 \qquad\qquad [2]$$

The second evaluation rule pertains to the cumulative Cost Performance Index (CPI). The CPI is earned value divided by actual cost, and can be computed based on a single month, an average of several months, or all months to date (cumulative). When the cumulative CPI is less than one, an adverse cost variance (i.e., a cost overrun) is indicated.

$$\text{CPI} \quad = \quad \text{Earned Value} / \text{Actual Cost} \qquad\qquad [3]$$

We computed the cumulative CV and CPI at the 20 percent completion point (CV20 and CPI20) and at the end of the contract (CV final and CPI final) for each contract in our sample. Percent complete was defined as cumulative earned value divided by the total budget for the planned work on the contract, termed the Budget At Completion (BAC).

$$\text{Percent Complete} \quad = \quad \text{Cumulative Earned Value} / \text{BAC} \qquad\qquad [4]$$

The 20 percent completion point was chosen because earlier performance data are often either not available or considered unreliable. For example, it has sometimes taken over one year for a contractor to be found compliant to the earned value management systems (EVMS) criteria, or to establish a performance measurement baseline (Fleming 1992). Until each is accomplished, performance measurement data are of dubious value.

Hypothesis 3 pertains to the stability of the cumulative CPI. Based on an analysis of 155 defense acquisition contracts, Christensen and Heise (1993) reported that the range of the cumulative CPI from the 20 percent completion point to contract completion was less than 0.20 for every contract. This result is usually interpreted to mean that the cumulative CPI does not change by more than plus or minus 0.10 from its value at the 20 percent completion point, and is used to evaluate the reasonableness of projected cost efficiencies on future work. For a description of the technique see Christensen (1999).

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[4] The budgeted cost of work performed is also known as BCWP. The actual cost of work performed is also known as ACWP.

Hypothesis 4 pertains to the remaining portion of the CPI rule: in most cases the cumulative CPI worsens. If the cumulative CPI at the 20 percent completion point is greater than the final CPI, then the cost variance worsened. The cumulative CPI is often used to determine a reasonable lower bound to the EAC. Since the A-12 cancellation (c1991), DOD policy requires that if the EAC derived from the cumulative CPI is larger than the EAC supported by the contractor, then the contractor's EAC needs to be explained.

The database

We collected contract performance data from the Defense Acquisition Executive Summary (DAES) database, maintained by the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD (AT&L)). The database contains cost and schedule performance data on more than 500 completed and on-going contracts from as early as 1971. A contractor prepares a monthly cost performance report (CPR) that summarizes cost and schedule performance, and sends it to the government program office for analysis. The program office summarizes the CPR data into a DAES report that is sent to OUSD (AT&L) for analysis and storage in the DAES database.

The reliability of the data is controlled by a DOD requirement for contractors to comply with Earned Value Management Systems (EVMS) criteria (DOD 1997). The criteria are internal controls intended to encourage adequate planning and control. When the contractor's management control systems are compliant to the EVMS criteria, the government assumes that the performance data are reasonably reliable. In general, contractors that submit the CPR are required to be EVMS criteria-compliant.

The sample

We identified 240 contracts with the necessary data to test the four hypotheses. The necessary data included values for cumulative earned value, cumulative actual cost, and BAC at the 20 percent completion point and after the 80 percent completion point. For the 20 percent completion point, we selected any contract with performance data within 17.5 and 22.5 percent. Because many contractors discontinue CPR reporting after the 80 percent completion point, we defined the final cost as the cumulative actual cost from the last available CPR for each contract, and included it if the percent complete exceeded 80 percent and we could match it with the same contract at the 20 percent completion point.

We tested each hypothesis on the entire sample and on various categories within the sample using the paired-t test and the non-parametric Mann-Whitney test. Previous research shows that cost variances are not normally distributed (Christensen, et al. 2000). Although the paired-t test is generally robust to modest violations of normality, we chose to include the non-parametric test for completeness (Conover 1980). All testing was conducted at an alpha of .05.

We chose 31 Dec 91, about one year after the A12 cancellation was announced, as a cut-off date for distinguishing pre-A12 contracts from post-A12 contracts. Virtually any cut-off date is arbitrary because the ability of the A12 cancellation to influence the "abiding cultural problem" described by Beach (1990) could take years. Accordingly, we divided our sample into three time periods (pre-A12, transitional, post-A12), and tested our hypotheses on each period. Pre-A12 contracts finished before 31 Dec 91. Transitional contracts started before but finished after 31 Dec 91. Post-A12 contracts started after 31 Dec 1991.

RESULTS

Hypotheses 1, 2 and 4

Tables 1-3 show the mean cost performance (expressed in dollars, percentages, and the cumulative CPI) at the 20 percent and at the 100 percent completion points for pre-A12, transitional, and post-A12 contracts, and for various sub-categories of these contracts.[5] These tables also show the results of testing hypotheses 1, 2 and 4. (The results of testing hypothesis 3 appear in Table 4). When the null hypothesis was rejected (indicated with an asterisk), the mean cost performance worsened significantly from the 20 percent completion point.

Pre-A12 Contracts. For the 147 pre-A12 contracts, the two EAC evaluation rules were confirmed (null hypotheses 1, 2, and 4 were rejected). The mean final cost variance (in dollars and as a percentage) and the mean final CPI were each significantly worse than their mean values at the 20 percent completion point. For example, Table1 shows that the mean final cost variance (CV FINAL) of the pre-A12 contracts was -$12.2 million. The mean cost variance at the 20% completion point (CV 20) was -$0.8 million. The mean difference (CV FINAL – CV 20) of

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[5] Some of the sub-categories do not add to the total because some contracts in the DAES database are not completely described.

-$11.4 million was statistically significant (one-tailed p < 0.000).[6] Tables 2 and 3 are interpreted the same way. For example, Table 3 shows that the mean final cumulative CPI (CPI FINAL) was 0.951, and the mean cumulative CPI at the 20% completion point (CPI 20) was 0.996. The mean difference (CPI FINAL – CPI 20) of -0.045 was highly significant (one-tailed p < 0.000). This result was the same for nearly all subcategories of pre-A12 contracts. The only exception was pre-A12 navy contracts, where the mean decrease in the cumulative CPI was not significant (one-tailed p = 0.054).

Post-A12 Contracts. For the 52 post-A12 contracts, the two EAC evaluation rules were not confirmed (null hypotheses 1, 2, and 4 were not rejected). The mean cost performance (measured as a percentage or as the cumulative CPI) of post-A12 contracts did not worsen significantly from the 20 percent completion point. For example, the mean CPI of the 52 post-A12 contracts at the 20% completion point was 0.977, and the mean final CPI was 0.964. The decrease of 0.013 was not significant (one-tailed p = .217). As shown in Tables 2 and 3, the only exceptions to this result were post-A12 development and army contracts. The mean cost performance of all other post-A12 contracts did not worsen significantly.[7]

Based on these results, we also tested whether the mean final cost performance on post-A12 contracts was significantly better than the mean final cost performance on pre-A12 contracts. Results showed that the mean improvement in cost performance of the post-A12 contracts was not significant, regardless of how cost performance was defined, and regardless of the contract category. For example, the mean final cost variance on the 147 pre-A12 contracts was -6.5%, and the mean final cost variance on the 52 post-A12 contracts was -4.4%. The mean difference of 2.1 % was not statistically significant (one-tailed p = 0.214).

 Hypothesis 3

Table 4 summarizes the results of testing hypothesis 3, pertaining to the stability of the cumulative CPI. With only a few exceptions, the stability of the cumulative CPI was confirmed (null hypothesis 3 was rejected). The mean cumulative CPI did not change by more than 0.10 from its mean value at the 20 percent completion point

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[6] All p values shown in the tables are based on the Mann-Whitney test. The results of the paired-test were consistent with the results of the Mann-Whitney test.
[7] We do not know why the mean cost performance of these sub-categories of post-A12 contracts was different than the rest; however, the small sample sizes of these categories may be a contributing factor. Accordingly, we place more confidence in the overall result, than the analysis of the smaller sub-categories. In addition, the analysis of cost variances in dollars (Table 1) shows slightly different results on post-A12 contracts. We suspect the differences are

(one-tailed p < 0.000). This was true, regardless of whether the contracts were pre-A12 or post-A12. For pre-A12 and post-A12 contracts, the mean absolute deviations in the cumulative CPI were .086 and .067, respectively, and each was significantly less than .10 (one-tailed p < 0.000).

There were some pre-A12 sub-categories (i.e., development, Army), where the mean absolute deviation of the cumulative CPI was not significantly less than 0.10. Although this result may appear to invalidate results reported by Christensen and Heise (1993), we used a more rigorous definition for CPI stability. Christensen and Heise (1993) defined the cumulative CPI to be stable when its range was within 0.20. We defined the cumulative CPI to be stable when its mean absolute deviation was less than 0.10, an arguably more stringent criterion. If we increased the mean absolute deviation to 0.20, our results would be entirely consistent with the results reported by Christensen and Heise (1993).

We also tested whether the mean absolute deviation of the cumulative final CPI on the post-A12 contracts was significantly smaller than the mean absolute deviation on pre-A12 contracts. Results showed that the decrease was not statistically significant. For the 147 pre-A12 contracts, the mean absolute deviation was .085. For the 52 post-A12 contracts, the deviation was 0.067. The mean difference of .018 is not significant (one-tailed p = .153). This was true of all subcategories of pre-A12 and post-A12 contracts.

CONCLUSION

The A12 cancellation was a bitter pill to swallow, but it appears to have done some good. The mean cost performance of pre-A12 (contracts that finished before 31 Dec 91) worsened significantly from the 20 percent completion point, regardless of the contract phase, contract type, or the military service managing the contract. For post-A12 contracts, the mean cost performance did not worsen significantly from the 20 percent completion point. However, the mean final cost performance on post-A12 contracts was not significantly better than the mean final cost performance on pre-A12 contracts. Taken together, these results suggest that while cost performance is improving, it would be unwise to stop using the EAC evaluation rules to encourage more realistic estimates. The A12 cancellation highlighted the use of these rules in arriving at a more realistic EAC (Beach 1990).

Our results suggest that the A12 cancellation was a "significant emotional event" that may have helped to correct the abiding cultural problem described by Beach (1990). Research shows that numerous prior initiatives to

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due to averaging dollars (Table 1) instead of ratios of dollars (Tables 2 and 3). Cost variances in dollars (CV$) could

reform defense acquisition have not reduced defense cost overruns (Drezner, et al. 1993). Accordingly, Green et al. (2000) conclude that when viewed through the "lens of past experience" today's reform initiatives are doomed to failure. We interpret our results as counter-evidence to their pessimistic projection. Things are getting better.[8]

Another consideration is the unexpected poor cost performance of the contracts that started before and finished after the A12 cancellation (transitional contracts). Cost performance for these contracts was much worse than the pre-A12 and post-A12 contracts. During this transition period, the DOD and contractors were changing systems (and probably cultures) to take advantage of acquisition reform initiatives. It appears that transitional contracts were not benefited by acquisition reform, and may have received adverse effects from proposing and contracting under pre-acquisition reform rules while all or part of actual contract performance occurred in the acquisition reform period. That may be the price of acquisition reform.

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be biased by inflation and differences in contract sizes.
[8] We recognize that improved cost performance is not the only indicator of success in defense acquisition reform.

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TABLE 1

MEAN COST VARIANCES ON DEFENSE ACQUISITION CONTRACTS
AT 20 PERCENT COMPLETE (CV 20) AND AT COMPLETION (CV FINAL)

		CV 20 ($Millions)		CV FINAL ($Millions)		CV FINAL – CV 20		MANN-WHITNEY TEST		
Category	N	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Asymp. Z	1-tailed p	
Pre-A12	147	-0.8	4.0	-12.2	45.4	-11.4	43.6	-5.72	0.000	*
Development	44	-1.4	4.5	-11.3	18.0	-9.9	15.2	-4.65	0.000	*
Production	49	-0.3	3.0	-9.9	26.3	-9.6	25.6	-3.23	0.001	*
Air Force	53	-0.3	3.7	-8.1	18.6	-7.8	16.8	-3.39	0.000	*
Army	45	-0.7	2.5	-12.7	21.8	-12.0	21.6	-3.98	0.000	*
Navy	49	-1.4	5.2	-16.2	73.7	-14.8	71.0	-2.46	0.007	*
Cost-reimbursable	53	-1.8	4.8	-22.5	69.2	-20.7	67.1	-4.47	0.000	*
Fixed-price	90	-0.2	3.3	-6.3	21.9	-6.2	20.1	-3.77	0.000	*
Trans-A12	41	-3.4	9.8	-120.8	464.6	-117.4	462.2	-4.21	0.000	*
Post-A12	52	-3.0	6.6	-15.8	39.3	-12.8	36.3	-2.42	0.008	*
Development	24	-0.8	2.2	-11.7	17.3	-10.9	16.8	-3.36	0.000	*
Production	26	-5.3	8.5	-20.9	53.0	-15.6	49.1	-0.83	0.205	
Air Force	12	-0.5	1.6	-7.5	19.2	-7.1	19.0	-0.39	0.348	
Army	14	-2.2	4.0	-21.5	39.6	-19.3	39.6	-2.35	0.009	*
Navy	26	-4.6	8.5	-16.6	46.0	-12.0	41.0	-1.21	0.114	
Cost-reimbursable	34	-1.5	3.1	-12.9	28.9	-11.4	28.8	-2.51	0.006	*
Fixed-price	15	-7.2	10.3	-25.1	59.0	-17.9	52.8	-0.97	0.167	

H1o: CV final – CV 20 $\geq$ 0 (The mean CV did not worsen from the 20% completion point)   * Reject Ho at alpha = .05
H1a: CV final – CV 20 < 0 (The mean CV worsened from the 20% completion point)

TABLE 2

MEAN COST VARIANCE PERCENTAGES ON DEFENSE ACQUISITION CONTRACTS
AT 20 PERCENT COMPLETE (CV% 20) AND AT COMPLETION (CV% FINAL)

| Category | N | CV% 20 | | CV% FINAL | | CV% FINAL – CV% 20 | | Mann-Whitney Test | | |
		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Asymp. Z	1-tailed p	
Pre-A12	147	-1.7	12.0	-6.5	13.2	-4.8	13.5	-4.90	0.000	*
Development	44	-2.0	13.8	-6.2	10.4	-4.2	14.4	-3.16	0.001	*
Production	49	-1.9	12.5	-8.1	14.4	-6.2	12.6	-3.18	0.001	*
Air Force	53	-2.0	14.5	-4.7	11.4	-2.7	12.6	-2.98	0.001	*
Army	45	-1.3	11.9	-9.8	16.5	-8.5	15.9	-3.60	0.000	*
Navy	49	-1.7	8.8	-5.5	11.1	-3.9	11.6	-1.70	0.044	*
Cost-reimbursable	53	-2.3	11.5	-8.7	15.5	-6.4	14.1	-3.47	0.000	*
Fixed-price	90	-1.2	12.4	-5.5	11.6	-4.3	13.2	-3.55	0.000	*
Trans-A12	41	-2.0	10.7	-13.9	17.0	-11.9	15.9	-4.01	0.000	*
Post-A12	52	-2.6	6.0	-4.4	9.1	-1.7	9.4	-0.57	0.286	
Development	24	-0.9	5.4	-5.8	7.7	-4.9	7.7	-3.36	0.000	*
Production	26	-4.3	6.3	-3.9	9.8	0.3	10.0	-0.83	0.795	
Air Force	12	0.3	4.5	-0.3	7.1	-0.5	7.4	0.00	0.500	
Army	14	-2.3	5.0	-7.9	10.8	-5.6	11.1	-1.66	0.048	*
Navy	26	-4.2	6.8	-4.4	8.5	-0.3	8.9	-0.65	0.258	
Cost-reimbursable	34	-1.5	4.9	-4.9	9.9	-3.4	9.7	-1.58	0.057	
Fixed-price	15	-5.8	7.0	-4.0	8.0	1.8	8.2	-1.19	0..884	

H2o: CV% final – CV% 20 $\geq$ 0 (The mean CV% did not worsen from the 20% completion point)   * Reject Ho at alpha = .05
H2a: CV% final – CV$ 20 < 0 (The mean CV% worsened from the 20% completion point)

TABLE 3

MEAN CUMULATIVE COST PERFORMANCE INDICES (CPI) ON DEFENSE ACQUISITION CONTRACTS
AT 20 PERCENT COMPLETE (CPI 20) AND AT COMPLETION (CPI FINAL)

Category	N	Cumulative CPI 20		Cum. CPI FINAL		CPI FINAL – CPI 20		Mann-Whitney Test		
		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Asymp. Z	1-tailed p	
Pre-A12	147	0.996	0.109	0.951	0.102	-0.045	0.112	-4.96	0.000	*
Development	44	0.996	0.124	0.949	0.085	-0.078	0.113	-3.31	0.000	*
Production	49	0.995	0.109	0.939	0.109	-0.055	0.111	-3.24	0.001	*
Air Force	53	0.996	0.116	0.965	0.086	-0.032	0.103	-3.05	0.001	*
Army	45	1.001	0.123	0.928	0.121	-0.071	0.124	-3.66	0.000	*
Navy	49	0.991	0.088	0.957	0.096	-0.034	0.107	-1.61	0.054	
Cost-reimbursable	53	0.989	0.107	0.935	0.108	-0.054	0.106	-3.55	0.000	*
Fixed-price	90	1.001	0.112	0.958	0.096	-0.066	0.115	-3.62	0.000	*
Trans-A12	41	0.990	0.095	0.896	0.125	-0.094	0.232	-3.99	0.000	*
Post-A12	52	0.977	0.056	0.964	0.077	-0.013	0.081	-0.61	0.271	
Development	24	0.994	0.053	0.949	0.063	-0.044	0.067	-2.57	0.005	*
Production	26	0.962	0.056	0.969	0.079	0.007	0.082	-1.23	0.891	
Air Force	12	1.005	0.047	1.002	0.074	-0.002	0.078	0.00	0.500	
Army	14	0.980	0.050	0.934	0.081	-0.045	0.087	-1.66	0.048	*
Navy	26	0.964	0.060	0.963	0.072	0.000	0.079	-0.60	0.725	
Cost-reimbursable	34	0.988	0.049	0.961	0.083	-0.027	0.082	-1.53	0.063	
Fixed-price	15	0.949	0.058	0.967	0.072	0.018	0.074	-1.14	0.872	

H4o: CPI final – CPI 20 ≥ 0 (The mean cumulative CPI did not worsen from the 20% completion point)   * Reject Ho at alpha = .05
H4a: CPI final – CPI 20 < 0 (The mean cumulative CPI worsened from the 20% completion point)

TABLE 4

CUMULATIVE COST PERFORMANCE INDEX STABILITY
ON DEFENSE ACQUISITION CONTRACTS

| Category | N | | CPI FINAL – CPI 20 | | | Mann-Whitney Test | | |
		Mean	Std Dev	Asymp. Z	1-tailed p	
Pre-A12	147	0.085	0.085	-3.405	0.000	*
Development	44	0.085	0.087	-1.610	0.054	
Production	49	0.086	0.089	-2.024	0.021	*
Air Force	53	0.075	0.077	-2.793	0.003	*
Army	45	0.105	0.096	-0.762	0.223	
Navy	49	0.078	0.081	-2.333	0.010	*
Cost-reimbursable	53	0.084	0.084	-2.421	0.008	*
Fixed-price	90	0.087	0.086	-2.428	0.008	*
Trans-A12	41	0.117	0.101	-0.032	0.487	
Post-A12	52	0.067	0.053	-4.207	0.000	*
Development	24	0.060	0.052	-3.000	0.001	*
Production	26	0.062	0.053	-3.111	0.001	*
Air Force	12	0.059	0.048	-2.118	0.017	*
Army	14	0.072	0.064	-1.789	0.037	*
Navy	26	0.059	0.050	-3.111	0.001	*
Cost-reimbursable	34	0.064	0.058	-3.171	0.001	*
Fixed-price	15	0.060	0.046	-2.329	0.010	*

H3o: | CPI final – CPI 20 | $\geq$ 0.10 (The mean absolute cum CPI changed by more than .10)
H3a: | CPI final – CPI 20 | < 0.10 (The mean absolute cum CPI did not change by more than .10)
* Reject Ho at alpha = .05.